SPECIAL RADIO INSTALLATIONS

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INTRODUCTION

Radio is no longer intended for only the home. It has become so much a part of our lives that radio receivers are now to be found in offices, automobiles, motor-boats, etc. Many a home boasts of its second radio, or its single powerful machine controlled from every convenient corner of the house. People when they go on their vacation often take a Radio with them, and where the universal receiver cannot be connected to a convenient power socket, the light, portable battery receiver is popular.

The radio service man will find the audio amplifier used extensively in conjunction with a microphone or a phono-pickup for rendering musical programs, or as an aid for public addresses. Although the subject is rather extensive, and deserves special additional study by the progressive service man, the simple phases of the subject will be considered in this text.

Certain conditions in the home, certain likes and dislikes of individuals and other influences are the governing factors in special built and special designed receivers. Service men are often called on to make special receiver installations to fulfill a certain desire of a customer who will not be satisfied with anything else. A custom built receiver may be a standard commercial receiver but modified and placed in another cabinet which is already in the home of the owner. Due to the odd shape of old antique pieces of furniture, the service man is called on to redesign a certain receiver or design one himself which will fit into the required cabinet and also give performance comparable to regular commercial jobs.

The radio set manufacturer today is very much concerned with the public's special desires and most special installations can be met with manufactured outfits. When special adaptations are necessary, the service man is in a position to show his originality. Much can be learned by reading the radio trade journals and wholesale mail order catalogs.

Remote control is gradually finding its place in the completely furnished, well appointed home, and if the clientele of the

service man indicates that there is a market for this form of radio adaptation, the service man should be in a position to adapt standard remote controls to existing machines.

Perhaps the most important development in special radio installations, is the receiver adapted to the automobile. This field has become permanent and very profitable.

In this text the student will consider special radio installations which have not been considered previously to any extent; that is, portable receivers, P.A. amplifiers, automobile radios and remote control.

UNIVERSAL AND PORTABLE RECEIVERS

A single receiver that is easily adapted to work on A.C., D.C., storage and B batteries, and 32 volt farm lighting systems is by no means an impossibility. *Universal* receivers are in demand. Usually they are small, compact affairs, about 10 inches long, 7 inches high and 5 inches wide, the circuit employing four or five tubes including the rectifier tube. These receivers make an excellent second receiver for the bedroom, den, or office. Because they may be used on any source of power and are light in weight, they can be quickly thrown into a traveling bag and taken to hotels, on vacations, on outings, to the hospital, in an automobile or motor-boat, or to the farm and quickly set up. Although they have these universal features, their performance cannot compare with a large console machine.

Figure 1a shows the external appearance of two typical universal receivers, one in a carrying case with the cover removed, the other one a desk or mantel model. Most universal receivers are designed simply for A.C. or D.C. operation. A power cord extends from the rear and is plugged into either an A.C. or D.C. outlet. A 25 foot flexible insulated wire serves as an aerial which may be thrown out the window or strung around the room or to some support. The electric line serves as the ground.

Universal receivers have been made possible with the introduction of low voltage, high vacuum rectifiers, and the perfection of heater type amplifiers, especially the new power output pentodes. The pentode tubes are capable of supplying a reasonably large output when operated at low plate voltage (90 to 110 volts) and low grid excitation. The amplifier and detector tubes used are of the 6.3 volt type, 0.3 ampere type, the

power amplifier of the 6.3 or 25 volt type, and the half-wave rectifier of the 6.3, 12, or 25 volt, 0.3 ampere type.

The filaments of the tubes and a suitable limiting resistance are connected in series. This permits direct connection to either a 110 volt A.C. or D.C. power outlet. The tubes being of the heater types, the signal circuit has no connection with the filament power supply. Because of the high temperature lag of the electron emitter, very little hum gets into the signal circuit from the filament supply. Hum output is of little importance anyway, as such receivers will not reproduce below 200 c.p.s.

The rectifier tube feeds into a simple brute force filter. When connected to an A. C. supply, normal half-wave rectification takes place. When connected to a D.C. supply, no rectification takes place, the rectifier merely acting as a conductor, but the commutator ripple usually found in D.C. supplies is filtered out. When connected to a D.C. supply, B voltage will only be fed to the receiver if the plug is properly poled to the outlet. If improperly connected, the half-wave rectifier will not pass direct current. Reversing the plug will be necessary if no noise or signal is heard.

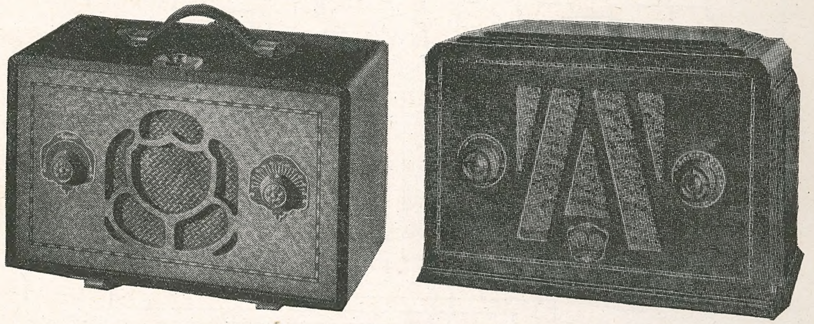


Fig. 1a

A possible universal receiver might consist of five type 6.3 volt tubes in series. Thus, the filaments would require 31.5 volts, and with a series limiting resistance the set may be operated from 220 or 110 volts A.C. or D.C., and, without this resistance, from a 32 volt power source. When the filaments are connected in parallel, by means of a suitable cable switching system, the filaments may be operated from a 6 volt storage battery.

This makes the receiver suitable for country or automobile use. When used on 6 or 32 volt supplies, batteries or a battery converter B supply will be required.

Calculating the series filament current limiting resistance illustrates the method of operating the filament. Suppose four type 6.3 volt tubes and a 25 volt rectifier tube are used. Then the total filament voltage drop will be 4 $\times$ 6.3 plus 25, which is equal to 50.2 volts. If the series current is 0.3 ampere, the limiting resistance should have a value of (110 — 50.2) $\div$ 0.3,

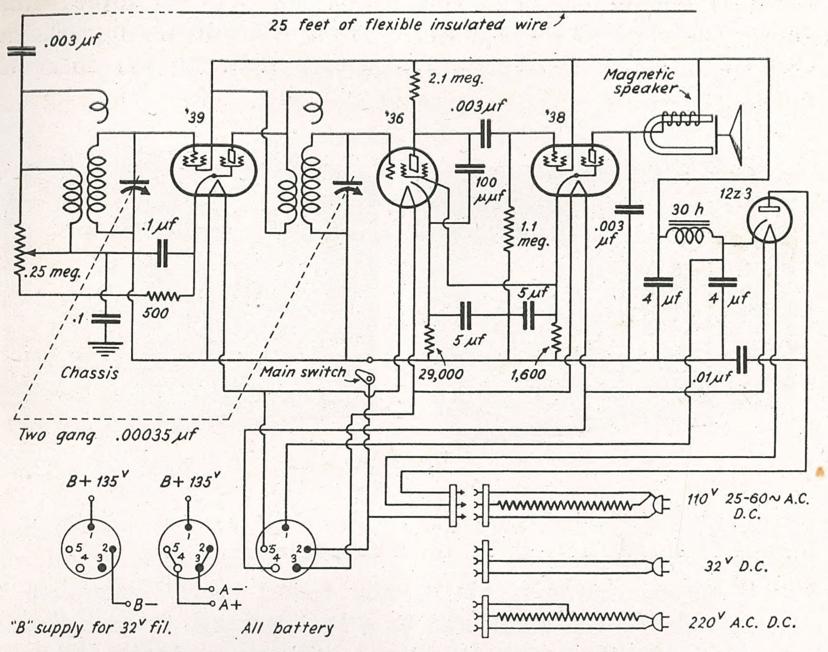


FIG. 1b

nearly equal to 200 ohms. The power lost in heat will be (110 — 50.2) $\times$ 0.3, nearly equal to 18 watts. This drop resistance may be built into the chassis, but, as the power loss developed may overheat the chassis, the use of a resistance built into the power cord is often used. If the power cable is of the plug-in type, any reasonable voltage supply may be used, as 110, 115, 220 volts A.C. or D.C., provided the proper cord is selected.

Selectivity and sensitivity are of major importance. Fidelity is out of the question because of the limited baffle asso-

ciated with the speaker. Well balanced four and five tube T.R.F. and superheterodyne circuits are used.

Figure 1b shows a typical four tube T.R.F. universal receiver. Note the voltage limiting resistor located in the cord. Note the rectifier plate connection when used on 220 volts. When used on 110 to 220 A.C. or D.C. outlet, only the power cord is used. When used on batteries the power cord is not used, and all connections are made through a battery cable fitting into a five prong receptacle. Note the battery plug connections. If a 32 volt supply is used, a power cord minus the built-in limiting resistance is needed. This cord connection does not supply voltage to the plate of the rectifier. Three 6.3 volt amplifier tubes and one 12 volt rectifier tube are used in the set. Therefore, the filaments require 6.3 $\times$ 3 + 12, or nearly 31 volts. The rectifier

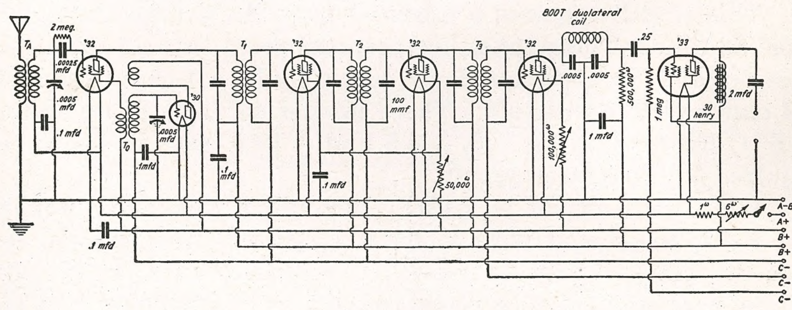


FIG. 1c

filament merely acts as a limiting resistor. The required B supply is fed through a special battery cable which connects the + and — of the B source to the circuit. Both battery and power leads may be combined in a single sheath if desired, and connected to a single plug.

The radio circuit consists of an antenna coupler feeding an R.F. pentode, which in turn couples to a screen grid detector through an R.F. transformer. Both transformers are designed to give uniform amplification over the entire tuning range. The power pentode is coupled to the detector through a resistance-capacitance coupler. A midget magnetic speaker then converts the A.F. signal into sound. The magnetic speaker is designed to have an impedance suitable for direct coupling to the pentode output tube, its wire being large enough to continuously handle the normal plate current. Important circuit values are shown.

There has always been a demand for portable receivers. A truly portable receiver is one that can be operated any place at any time. This necessarily means a battery operated receiver. Such receivers are much in demand for camping trips, picnics, beaches and other out-of-the-way places where alternating current or direct current is not available. However, the reproduction from these receivers is limited due to the necessity of a temporary aerial and a small number of tubes. Power tubes that could be used in these receivers formerly did not give enough volume. However, since the advent of the two volt tubes and especially the '33 type pentode two volt tube, reproduction from these receivers is much better. Receivers of this type usually employ a sensitive magnetic speaker. Portables are not easily obtained, so the constructional details of a satisfactory two dial battery superheterodyne receiver are given in Fig. 1c.

This circuit requires 6 tubes—1 type '30, 4 type '32 and 1 type '33 tube. These tubes are operated from two 1.5 dry cells in series and the voltage reduced to 2 volts by a 1 ohm fixed and a 4 ohm variable resistors. Three midget 45^v B batteries and a 13.5^v C battery having -3, -4.5 and -13.5^v taps will also be required for the power supply.

What coils should be used? Beginning with the antenna coil T_A, a $167\mu h$ coil with a .0005 variable condenser will be needed. The coil may be made by winding 59 turns of No. 28 enamel wire on a $1\frac{3}{4}$ inch round bakelite tube. If the set is to be connected to short aerials, which is more than likely with a portable receiver, about 25 turns of No. 28 enamel wire should be wound on the tubing, starting about $\frac{1}{4}$ inch away from the secondary at the end opposite to the grid connection.

A coil for the oscillator T_o can be easily built by the set builder. Again we shall use a .0005 variable condenser. As it is desirable to have the dial readings of the antenna condenser and the oscillator condenser as nearly alike as possible, a coil having less inductance than T_A will be needed. Using a .0005 variable condenser a coil with about $110\mu h$ will be required. This inductance can be obtained with a coil made by winding 45 turns of No. 28 enamel wire on a bakelite tubing $1\frac{3}{4}$ inch in diameter. The tickler should contain about 30 turns of the same wire and the link about 10 turns. Be sure that T_A and T_o are at right angles to each other and that enough precaution be taken to prevent one from coupling with the other.

Transformers T_1, T_2 and T_3 should not be built, instead they

should be purchased from a reliable wholesale parts distributor. There are several makes on the market which are designed to amplify at 175 kc.*

A '32 screen grid tube with a fixed C bias of -4.5 volts serves as the second detector. A variable 100,000 ohm resistor is adjusted for best detector action and then remains fixed. Note the pi (π) R.F. choke system. All details are given. The duolateral wound coils may be purchased from a parts distributor.

The resistance coupled audio system is easily assembled from standard parts. Note that the grid leak resistance connects to the -13.5^v C battery terminal. A light weight 30 henry choke with a 2mfd. blocking condenser serves as the output system. The magnetic speaker should have an impedance of 7000 ohms at 250 c.p.s. Of course an output transformer may be used and it should have a turn ratio to match the speaker impedance to the desired impedance of 7000 ohms.

AUTOMOBILE RADIO

Within the last few years serious development work has been carried out by competent engineers introducing a Radio receiver which can be neatly installed in any type of automobile, and capable of getting approximately the same reception in the motor car as the midget set in the home.

As the amount of pick-up possible with an automobile installation is limited, the receiver used must be extremely sensitive. Furthermore, it should be compactly designed, to be placed out of sight, and should be able to withstand shocks, vibration and extreme changes in temperature. Because of the ignition system necessary to operate the car motor, the set must be well shielded and installed so as to avoid direct interference from sparks or radio interference waves from the cable leads.

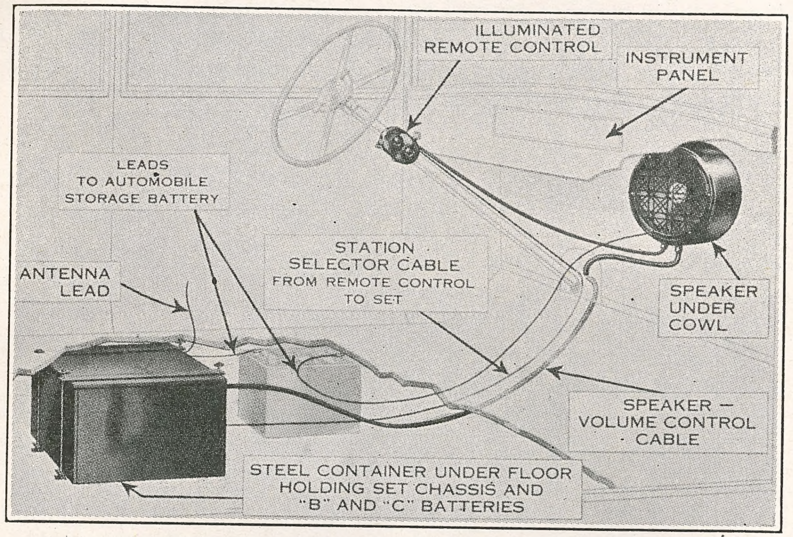
Practically all modern auto receivers are built to use the 6.3 volt indirectly heated cathode tubes, so they may be operated in parallel from the car storage battery. Some of the older receivers employ the 5 volt tubes in parallel and a common series limiting resistance. Others use a combination of 2.5 and 5 volt tubes with equalizing resistors. That was before the automobile type tubes were available.

The superheterodyne circuit is universally used in modern receivers, although the T.R.F. circuit, using at least four tuned sections, was employed in the older receivers. Because the pick-

* The method of synchronizing the I.F. stage is given elsewhere in the Course.

up is bound to vary while the car is in motion, automatic volume control is an essential circuit addition. The only difference between the auto and home receiver is the power supply. Power to feed the filaments is derived from the car battery; power for the other tube operating voltages is usually supplied by dry batteries, dynamotors or B eliminators. The latter two devices derive their power from the car battery.

Figure 2a shows one possible receiver assembly. The receiver is housed in a steel case; the speaker, either of the magnetic or dynamic type, is in a separate steel housing. A station selector with a tuning dial, an off-and-on switch, and a volume con-



Typical Automobile Radio Installation—Atwater Kent

trol connects to the main receiver by means of an electrical cord, and a flexible mechanical torque cable, the latter turning the condensers of the receiver. The mechanical drive is much like the drive used on speedometers for automobiles. The control box is mounted on the steering wheel column or on the dashboard. A shielded antenna lead and a power supply cable complete the essential parts of the receiver. Figure 2b shows an arrangement where the speaker is built into the receiver housing.

One pole of the car battery is connected to the steel frame of the automobile and is referred to as the ground. The other battery pole is referred to as the "hot" terminal—we will call it

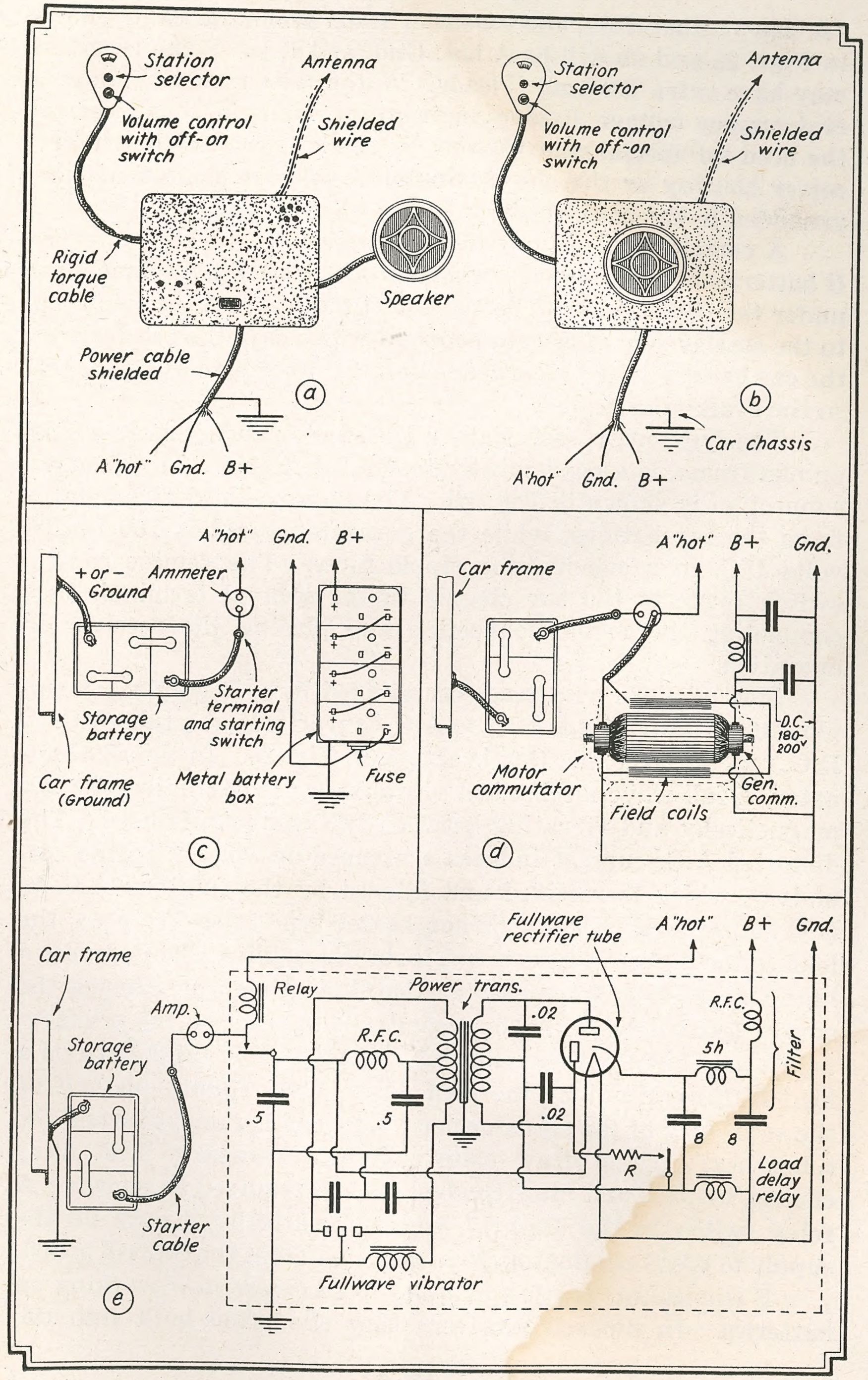


FIG. 2

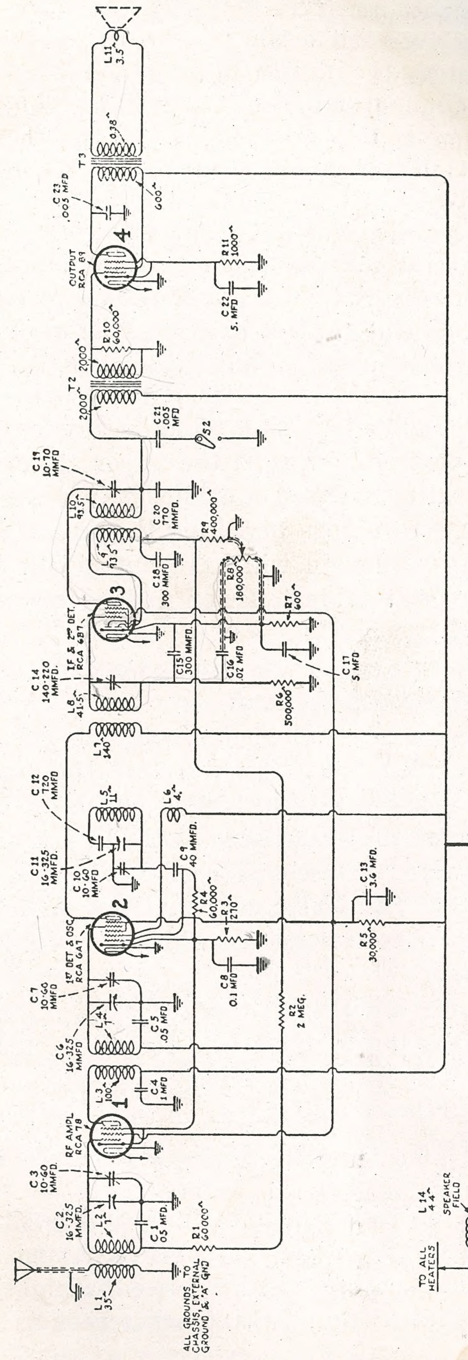
"A hot." Therefore, the essential leads from the cable shown in Figs. 2a and 2b will be A hot, Gnd. and B+. Some receivers may have extra B+ and C leads. Automobile receivers, in general, employ voltage dividers built into the chassis, thus reducing the need for special external voltage connections. Either the receiver housing or the shield around the power cable is usually grounded to the car chassis.

A complete battery arrangement is shown in Fig. 2c. The B batteries should be in a weather-proof metal housing, mounted under the floor board. The "A hot" terminal may be connected to the starter side of the ammeter, in which case the set drain on the car battery is not recorded, or on the other side of the meter, so the drain is indicated.

The dynamotor, essentially a D.C. motor and generator built on one frame, is a good substitute for B batteries. A schematic connection is shown in Fig. 2d. The motor side derives power from the car battery, while the generator supplies 180 to 200 volts D.C. to a commutator ripple filter. The remote control switch connects the car chassis to the ground terminal, thus completing the motor connection and placing the receiver in operation.

Most modern auto receivers are fed by a B eliminator employing a vibrator type D.C. to A.C. converter and a tube A.C. to D.C. rectifier system. One is shown in Fig. 2e. In this B eliminator, a full-wave mechanical vibrator, a reed-actuated electromagnetically and vibrating between two contacts, is used. The distorted A.C. current induces a stepped-up voltage in the secondary, which is rectified and filtered by the familiar A.C. to D.C. power pack system. When heater type tubes are used, the load to the power system is not instantly applied. This causes a high voltage to be impressed on the filter condenser, causing the surges (peak voltages in the secondary) to react on the primary, which may burn out the vibrator contacts. For these reasons a load *R*, thrown out by the load delay relay, shunts one-half of the secondary of the transformer. The load is removed when the tubes heat up and draw plate current. Necessary R.F. filter chokes, by-pass and filter condensers are required as shown. A relay switch in the "A hot" lead automatically throws on the supply to the B eliminator when actuated from the control board.

B eliminators may be adapted to receivers now working on batteries. In modern receivers they are often built into the



General Electric Model B-40 Automobile Radio: This modern superheterodyne circuit has a single R.F. pretuner. The first detector and oscillator is made possible with the pentagrid converter 6A7 type tube. The next tube, a duo diode pentode, serves as a combined I.F. amplifier, second detector and A.V.C. tube. The 89 output tube is connected as a power pentode.

The B eliminator is of the tubeless type employing a mechanical D.C. to A.C. generator and A.C. to D.C. rectifier. Note that the vibrating reed simultaneously closes one side of the primary and at the same time connects the secondary properly poled to the brute force filter. The field of the dynamic speaker is fed from the car battery. Switch S_1, located on the control box, closes the relay switch L_{15} and starts the power system. In this receiver the power supply, receiver and speaker are housed in one unit as shown in Fig. 2b.

speaker housing. In compact receivers they are built into the housing containing the receiver and speaker.

Be sure to carefully study the installation instructions of an automobile receiver or B eliminator that you may be called on to install before proceeding with the work.

Antenna Installation: Many of the latest models of automobiles have an antenna built in the inside of the top. This may consist of screen wire or parallel wires extending the length of the automobile top. In case the automobile does not have a built-in antenna then it will be necessary to install one. Copper screening is the most desirable as single wires placed in the top may cause serious directional effects and fading. This copper screen wire can be procured at any hardware dealer at a very reasonable cost. In building automobile tops some manufacturers place common poultry netting or screen wire in the upper structure of the top. As this is usually grounded it cannot be used as an antenna and must be removed before installing the antenna of the receiver. The wise service man will have automobile top repairman make this type of aerial installation under his supervision.

The installation of the antenna in cars having wooden framework may be briefly summarized as follows:

(A) It will be necessary to unfasten the front and sides of the head-lining, the back end remaining untouched, then carefully remove the backs from the listing strips, which are the muslin strips used to support the head-lining at the bows.

(B) Cut the screen wire as closely as possible to the sides, front and back of the car. Particular care must be observed that no sharp, protruding wires are exposed which may cut into the top fabric or head-lining.

(C) Remove the screen wire as well as the staples which are used to fasten it to the top of the bow. It will be found convenient to remove the wire in small sections.

(D) Stretch the upholstered webbing from the back to the front of the car on the bows. The number of strips to be used depends on the type of car.

(E) Tack the copper antenna screen securely into position making sure that it is separated from the dome light and the metal body of the car by at least three inches. See that lighting wires in the roof are separated from the antenna screen as far as possible.

(F) Securely solder the lead-in wire to the corner of the screen nearest the receiving set.

(G) Test the antenna for possible grounds by means of a voltmeter and battery. This test should be made from the antenna lead-in to any metallic part of the chassis.

(H) Carefully replace the car head-lining, working from the middle of each listing strip, progressing toward the front of the car. After the listing strips are in position the sides and front of the head-lining should be replaced.

(I) Retest the antenna for possible ground.

In cars of the open type, that is touring cars and roadsters, the method of installing the antenna differs considerably from that of the closed car type. The most satisfactory antenna for this type of car consists of from 65 to 100 feet of No. 18 gauge rubber covered, stranded wire, laced in grid formation in drill cloth and sandwiched between the top of the car and a head-lining of the same material. If the car is not already equipped with a head-lining the extra material may be procured from a local dealer in automobile fabrics. The stranded wire should be woven back and forth through holes punched in the drill cloth and be so located that the parallel sections of the wire do not approach closer than three inches to each other.

The antenna lead-in in this type of installation must be taken from the back end of the car. It may be carried to the dash in a groove cut in the floor board or it may be run underneath the body of the car. The antenna lead-in should always be run on the set side of the dash. If the lead-in is carried through the motor compartment it may be difficult to eliminate the ignition disturbances.

In some automobiles the bows are made of metal. Considering the high frequency leakage and the shielding effect that exist when the antenna is located too close to a metalic body, it will at once be seen that the copper screen will not constitute an efficient antenna in bodies of this particular construction. Here, as in the open car, the only logical solution to the problem is to resort to the insulated, stranded wire antenna properly separated from the metal bows. A number of staples or screw eyes should be securely fastened around the top frame of the car and separated from the metal bows by not less than three inches. As the top frame is relatively close to the metal body, the stranded antenna wire must not be laced directly through the staples or screw eyes. A section of heavy twine must be

tacked to the top frame, and carried through the screw eyes or staples in loop fashion. These loops must be long enough to afford the proper separation from the metal structure, after which the antenna wire should be laced grid fashion through the twine loops.

In the case of large buses it is possible to install the antenna on top of the bus, running the wires parallel with the length of the bus. It is essential that the aerial be erected about a foot above the top of the bus.

One popular make of manufactured set uses the capacitor or condenser plate type of aerial. This consists of a large metal plate placed parallel with and a short distance from the running board of the automobile. This capacitor plate is of course insulated from the running board and the chassis of the automobile and is connected to the aerial binding post of the receiver preferably with shielded wire. This type of antenna is not as efficient as other types of aerials unless the receiver is designed especially for this type of installation. It is not as sensitive as the copper screen type of aerial and also has the undesirable tendency of picking up more interference from the ignition system of the receiver than the screen aerial.

The ground connection of automobile receivers is made to the metal chassis of the automobile which acts as a counterpoise or substitute ground to the set.

Elimination of Interference: In order to understand the methods used in eliminating interference in automobile receivers, it is first necessary to understand, in a general way, the causes of the interference. In the first place the ignition system of an automobile is a miniature spark transmitting station. When the ignition system is in operation, the high tension wires, which carry high tension current to the spark plugs and the distributor, radiate energy just as the aerial of a transmitting station radiates electric waves. This energy is induced into the low tension wiring in the automobile and also into any metallic rods or parts situated in the engine compartment, and may in turn be picked up by the radio receiver. These high tension wires and metallic objects are, in most cases, surrounded by the engine hood, radiator, cowl and engine partition which act as a shield surrounding and confining the powerful magnetic fields set up in the engine compartment. In this case the use of standard spark suppressors and condensers will eliminate all the interfer-

ence, especially if the receiver is placed outside of the engine compartment.

It sometimes happens, however, that the interference will be induced into low tension wires or cables running out of the engine compartment to other parts of the automobile. In this case, the interference may be radiated from the low tension wiring system outside of the engine compartment and picked up by the receiver antenna system. On the other hand, modern automobiles have numerous rods such as heater rods, adjusting choke rods, and oil pipes running through the engine partition. These, too, may have induced in them interfering currents which eventually may reach the receiver.

It will be seen from this that the most convenient and effective method of preventing any transfer of energy from the motor compartment to the receiver is to separate all the low tension wires of the car as far as possible from the high tension wires of the ignition system. In some automobiles, the manufacturers group the low tension wires leading to various accessories, such as the horn and windshield wiper, within the high tension manifold, thus making an easy and neat installation. This practice will in all probability, cause trouble if a receiver is placed in an automobile. If the ordinary methods of eliminating interference as explained in the following paragraphs do not eliminate all the interference, it may be necessary to separate the high tension leads from the low tension wiring as much as possible.

In all ordinary installations, interference originating at the spark plugs can be eliminated by the use of spark suppressors consisting of high resistor units of approximately 20,000 to 30,000 ohms, connected directly to the spark plugs. They are connected as shown in Fig. 3. It is also generally necessary to connect a 1 mfd. condenser in series with the "high" side of the ignition coil to the frame of the car and a resistor in the lead from the coil to the distributor head as shown in Fig. 4. A second condenser of from 1 to 4 mfd. capacity is connected between the generator and the frame of the car. This is the standard method of interference elimination and it will be found successful in practically all cases.

Some radio service men are under the impression that a condenser should be placed across the breaker contacts in the ignition circuit. While this practice would eliminate practically all interference, in nearly all cases it would interfere with the operation of the automobile, especially at high speeds.

A spark occurs at each distributor contact at the same time that it occurs across the spark plug gap. This spark may be minimized by reducing the gap length of the distributor contacts. The rotor element may be lengthened slightly by hammering it carefully. The rotor element should not touch any of the distributor points but the gap should be as small as possible.

In case unusual interference is encountered, it will be necessary to bond or ground the various rods and wiring which run out of the engine compartment. In case of wiring which does not have a metallic covering, it will be necessary to place the wire in a metal conduit or use shielded wire. The shields of all such wires and also any other metallic rods should be grounded. This is done by soldering a short piece of flexible wire to the rod

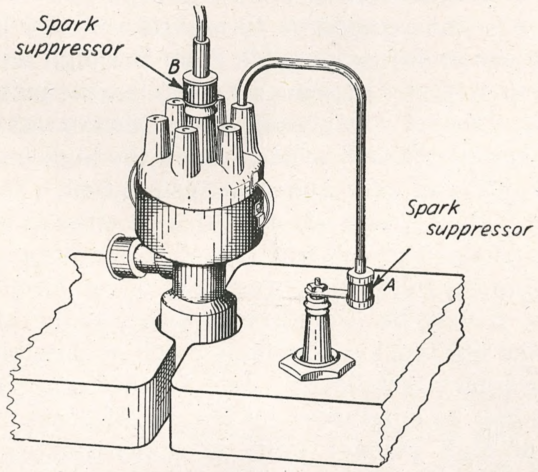


Fig. 3

or shield and grounding it to the frame of the car. This ground connection should not be over $1\frac{1}{2}$ to 3 inches long as otherwise it will act as a miniature transmitting antenna and radiate an interfering wave which will be picked up by the receiver. In very obstinate cases, it may be necessary to place these ground connections every 6 or 8 inches along the rod or cable which is radiating the interference. This may probably give the impression that all metallic rods and all shileding should be grounded at several points. This is not always the case as it sometimes happens that too many grounds will do more harm than good. The proper grounding method can only be determined by experiment.

The Radio-Trician will find that placing the receiver out-

side of the engine compartment, that is, placing the receiver itself on the side of the cowl next to the driver, will greatly reduce the amount of interference picked up by the set. In fact, it is never advisable to place the receiving set inside the engine compartment if it is possible to place it elsewhere. If it is absolutely necessary to put the receiver on the engine side of the cowl, then it should be placed as far as possible from the high tension coil and all high tension leads. In some instances, particularly the Model A Ford, it is best to change the location of the coil, placing it as far to one side of the engine compartment as pos-

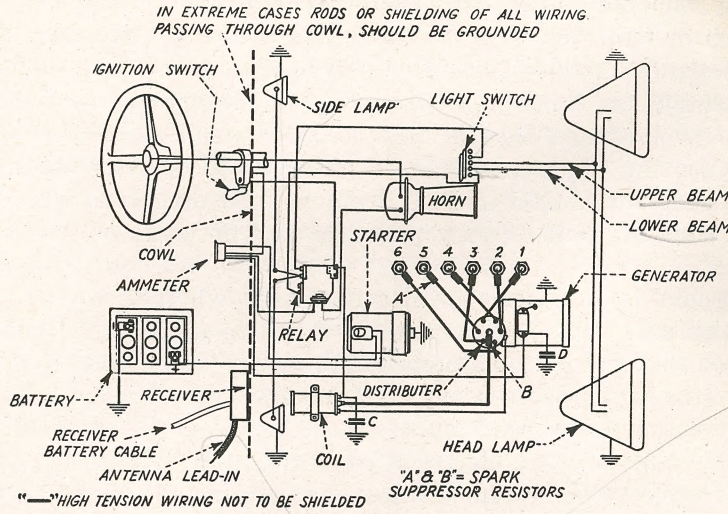


Fig. 4

sible, keeping the receiver near the other side of the compartment.

In placing the antenna in the top of the automobile it is best to use a shielded lead-in wire. This shielded wire should be of the ordinary type of small BX cable used in auto ignition wiring.

The shield must be very securely grounded where it is connected to the antenna and also next to the receiver. Care must, of course, be taken to see that the antenna itself is not grounded. The antenna should not come in close proximity to any of the wiring in the automobile and a space of 3 or 4 inches should always be allowed between the antenna and any grounded object or any wires or lights, such as the dome light of the automobile. In extreme cases it may be necessary to shield the battery cable of the receiver and ground it at several places.

It is well for the Radio-Trician to understand that no two automobile installations are alike. An installation may be made in one car without any trouble at all while in the very next installation in the same model of car, very obstinate interference may be encountered.

SOUND INSTALLATIONS

The service man today is finding a growing demand for sound installations in restaurants, dance halls, lecture halls, skating rinks, factories, schools, hospitals, hotels, etc. In every case the system boils down to a sound pick-up device, phonograph pickup or microphone or both, amplified to a desired level and projected by means of loudspeakers to the audience.

Simple as this sounds, sound installations are in general quite involved and we can only consider small simple installations, leaving the more advanced phases to those interested in a more complete course in P.A. systems. Nevertheless, what we shall consider will be very practical and of value as a money maker.

Sound installations are classified as to whether they are indoor or outdoor. Fundamentally they are alike with the exception that the indoor system requires less power and the room where the loudspeakers are placed requires special sound (acoustic) treatment. Special loudspeakers are used for outdoor and indoor systems. The electrical connections are identical.

The electrical system of a sound system may be broken down into: (1) the pickup device, (2) the loudspeakers, (3) the amplifier system which consists of the voltage and power amplifier stages, (4) the connection wires or transmission lines, (5) the volume (mixer) controls, and (6) the impedance matching devices—for it is not good practice to connect one part of the system with the next, without matching their impedances. These devices are generally found in a sound installation in a definite and orderly manner which may be expressed diagramatically as shown in Fig. 5. In particular, notice that whenever one device feeds into the next, an impedance matching transformer is used. The microphone and speakers are usually some distance away (20 feet may be considered a sufficiently long distance) from the amplifier systems. Therefore we must consider the wire connector as a transmission line. The importance of a transmission line will shortly be apparent.

Pick-ups: For the ordinary sound system, the double carbon

microphone and the magnetic phono-pickup are most generally used. A radio receiver (R.F. and detector unit) may also be a part of the system. Both devices have been considered in detail before. Let us consider the devices used together in the same system as would be the case if an installation were made at an athletic field. We must look ahead a little. The amplifier would naturally be built with an input transformer and the amplifier specification would state that it is to be fed from a definite impedance value. This will be obvious when we consider the amplifier. The phono-pickup has a definite impedance (usually about 10,000 ohms) and the double button carbon microphone has a total impedance of 400 ohms–200 ohms per button. Let us say that the input impedance rating of the amplifier is 500 ohms, the radio receiver has an output impedance of 4,000 ohms, the phono-pickup 10,000 ohms and the microphone 400 ohms. The last three items are to be connected in parallel and fed to the amplifier—its combined impedance—if there is to be no loss, must be 500 ohms. The arrangement must permit us to use all or only one at a time—that is, a mixer is required.

Without going into detail, let us see what is actually done. Refer to Fig. 6. The parts within the dotted lines constitute the mixer and impedance matching systems, and in practice the assembly is purchased complete from the manufacturer. All that you need to tell him is what you are putting into the mixer and what is the input impedance of the amplifiers. Three 3-contact plugs and jacks will be required, and the pick-up devices are connected as shown. Each jack connects to a matching transformer which reduces each device connected to it to a common impedance value. Let us say 500 ohms. To do this, T_1, T_2 must have a step-down ratio of 3, 4.5 respectively and T_3 a step-up ratio of 1.1.* Each matching transformer feeds into a volume control of special construction—usually called a constant impedance variable pad or attenuator. It should have a constant value of 500 ohms, that is, the impedance between *1* and *2* (input) or *2* and *3* (output) should always be 500 ohms no matter what position the slider is in. In spite of this fact it still acts as a variable voltage divider (volume control). If the slider is at *2*, no signal will be fed to the output; if at *3*, maximum signal will be forwarded.

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* Ratio $= \sqrt{\dfrac{\textit{large impedance}}{\text{small impedance}}}$: step-up if small impedance feeds into large impedance.

If the outputs of the three pads are connected in series their combined value would be 3×500 or 1500 ohms, if connected in parallel, the net impedance will be $500 \div 3$ or 167 ohms. Transformer T_4 is the master transformer and collects the signals from T_1, T_2 and T_3 and feeds the result to the input of the amplifier system. Hence T_4 should match either 1500 or 167 ohms to the 500 ohm amplifier input impedance. In the first case a step-down transformer of 1.7 and in the latter case a step-up ratio transformer of 1.7 will be required. Jacks J_1 are for a milliameter (0 to 10 ma) to indicate the microphone current and tell if both buttons are drawing the same current. The pads look exactly like a double volume control.

If the radio set were omitted, T_1 and P_1 would be eliminated. In this case T_4 would merely have to match 1000 or 250 ohms to

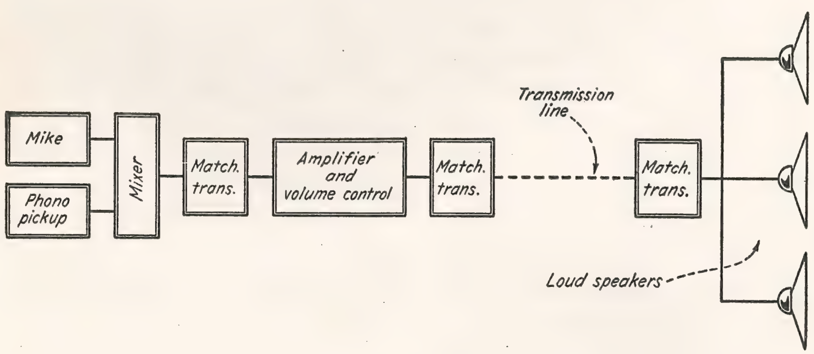


Fig. 5

the 500 ohm input. In many cases either the mike or phono-pickup would be used alone. Consider the mike only. Then the apparatus required from the microphone to the amplifier input will be T_3, a 400 to 500 ohm matching transformer, a battery, a variable resistor, and jacks for a milliammeter.

Loudspeaker: The usual dynamic speaker with a flat baffle is rarely used in P.A. systems, although in small installations their use would not be serious. In general, long horns with dynamic units are best suited for P.A. systems. The straight horn resembling a morning glory—called a morning glory horn is best adapted to outdoor use. The long exponential that is wound into a compact space is adapted to indoor use when placed behind grille work or screens. Morning glory speakers are also used indoors and with varying lengths so that all frequency ranges may be reproduced.

Single speakers may be obtained capable of handling as much as 30 watts, but in general, a 6 watt speaker should be used. If possible, feed them normally with only 5 watts of power so that overloading in emergency will not be serious. If the system requires 18 watts, 3 speakers could be used, but 4 would be preferable. The manufacturer will advise you the impedance of their dynamic unit or supply you with the proper coupling transformer if you tell him how many speakers you will need, how they are to be connected and to what they are to be connected.

A dynamic unit will as an average have an impedance of 10 ohms. If they are connected in series, the speaker system will

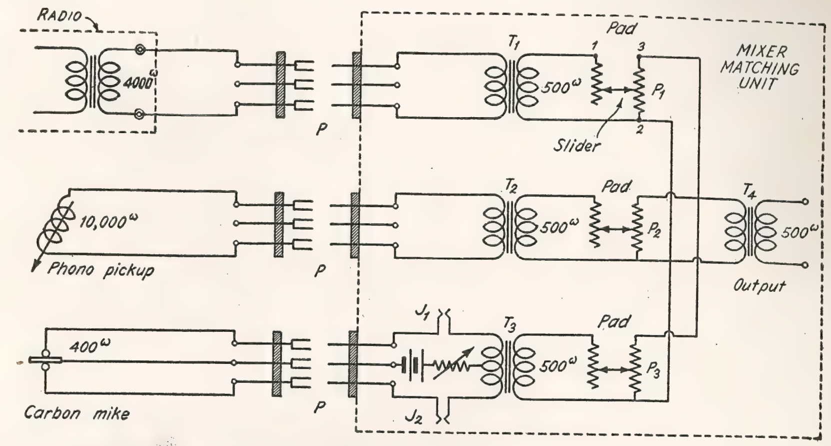
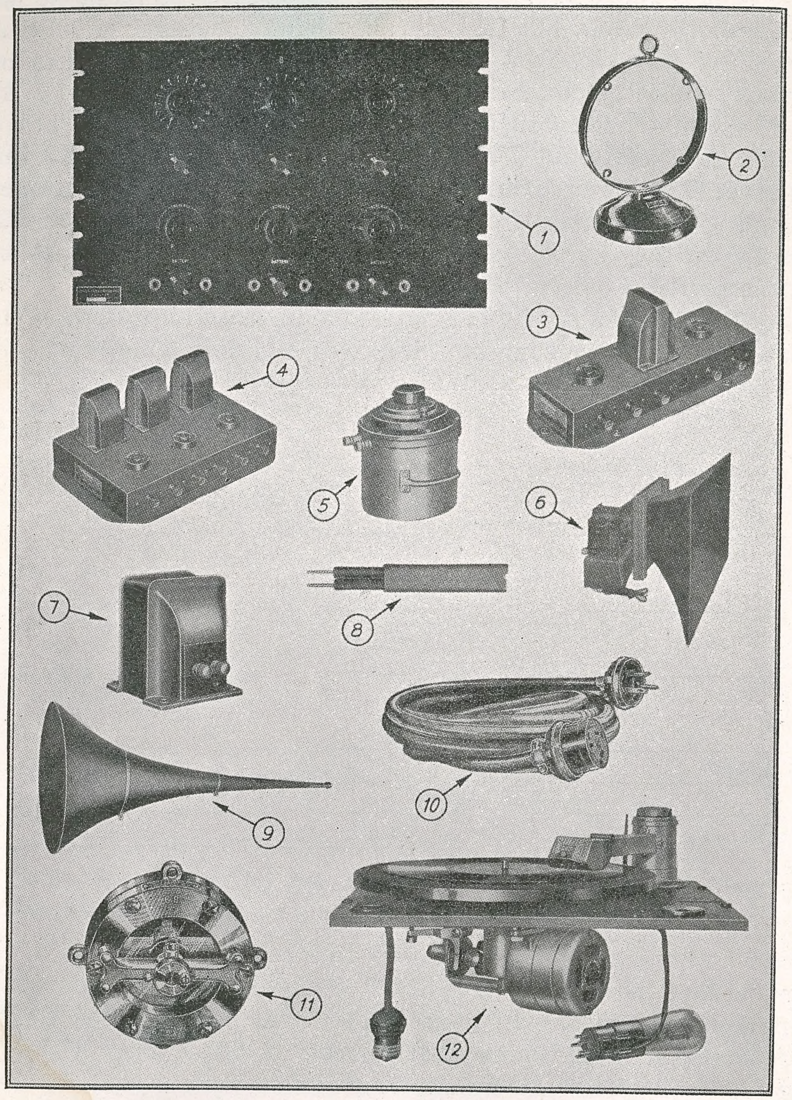


Fig. 6

have an impedance of 10 times the number of speakers used. If in parallel the impedance will be 10 divided by the number of speakers employed. In general they will be connected to the transmission line, which has a value of 500 ohms. Using 2 speakers in series the transformer should have a ratio of 5 to match 500 to 20 ohms, connecting the many turns of winding to the transmission line.

The loudspeaker will be so far away from the power amplifier and its power supply, that it would not be advisable to tap the latter for current to excite the dynamic units. When dynamic speakers are used, the fields can be excited from a storage battery, a dry disc rectifier system, or a vacuum tube rectifier, the latter two built into the speaker.



1. Jenkins and Adair 3-input Mixer Panel.
2. Desk Stand for Microphone.
3. Samson Output Power Stage.
4. Samson Voltage Amplifier.
5. Racon Dynamic Speaker Unit.
6. Dynamic Speaker with Directional Baffle.
7. Samson Impedance Matching Transformer.
8. Shielded Two Wire Cable.
9. Morning Glory (Trumpet) Horn.
10. Microphone Cable.
11. Universal Double-button Microphone.
12. Pacent Phono-pickup and Turntable.

How many speakers you use will depend on the power required to fill the space with sufficient sound energy. There is no simple way of determining this value. Much depends on the efficiency of loudspeakers, the conditions of the space or hall and the demands of the audience. Engineers have expressed their opinions which are given to you by curves in Figs. 7a and 7b. For outdoor systems, knowing the area to be covered, or for indoor systems knowing the number of people in the audience, the power required from the amplifier—speakers is easily determined. For noisy space you may increase the requirement 20 per cent. For small indoor or outdoor gatherings 11.5 watts power will be sufficient—this is equivalent to an amplifier having

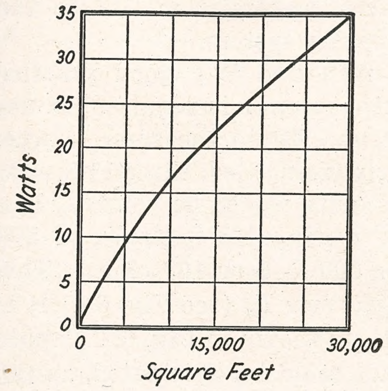


Fig. 7a

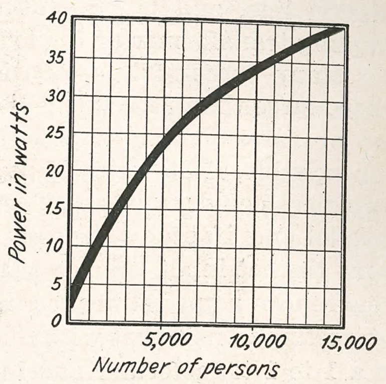


Fig. 7b

2 '50 tubes in push-pull in the output stage. With this requirement two 6 watt dynamic speakers will be needed.

Amplifiers: The first desire that the serviceman has, is to build the amplifier, but the progressive man will purchase the amplifier. It takes a good workshop to turn out a commercial looking amplifier. Complete sound amplifier systems may be purchased from a manufacturer and for large installations this is the most advisable procedure. Most amplifier makers produce an amplifier with two type '50 tubes in push-pull output. Some makes have only one audio preceding the output stage. In this case a voltage amplifier will be required ahead of the power amplifier. For normal inputs from a microphone or phono-pickup, two stages of voltage amplification ahead of the power stage will be sufficient. The power supply should be an integral part of the amplifier.

An amplifier should be preferably used that has built into it a volume control. This is not absolutely essential as a variable pad may be connected between T_4 (see Fig. 6) and the input of the amplifier. However, these volume controls are costly and best omitted.

Amplifiers are rated as to power output, output impedance, input impedance and r.m.s. voltage input for maximum power. All this information is essential if a good match between parts of the system is desired. The average amplifier will have an input and output impedance of 500 ohms and will require about 0.3 volt r.m.s. input signal. A normal phono-pickup or sensitive double button microphone will deliver about this value. The input would be connected to T_4 (see Fig. 6) the output to a transmission line, and the output of the transmission line to the coupling transformer of the loudspeaker system.

Many successful installation men find it a good practice where more than 11.5 watts of output power is required, to use two or more similar amplifiers connected to the same source. For example, if 35 watts of power were needed, three 11.5 watt amplifiers could be used. Their inputs would be connected in parallel and if each amplifier had an input impedance of 500 ohms the net input value would be 500 ÷ 3 or 167 ohms. This would mean a special master transformer T_4 (see Fig. 6). It is interesting to note that with the set-up shown in Fig. 6, T_4 would be a 1 to 1 transformer and in fact could be eliminated, as the match is exact without its use.

Where more than one amplifier is needed the accepted practice is to use power amplifiers with only one voltage amplifier stage preceding the power stage and to use a standard 2 stage voltage amplifier ahead of this unit. Enough power amplifiers are then purchased to meet the power required, their inputs connected in parallel and wired to the voltage amplifier output. Perfect match between units is essential. Note that we have stressed matching throughout this problem. A perfect match, the insertion of volume controls whose input and output impedance remains constant at any position, the assurance that no tube is operating above the allowable grid swing (normal level at every point) and that sufficient amplification is obtained are the cardinal points in signal amplifier systems for sound installations.*

* These four factors are very important.

Transmission Lines: When a connector or double connector is more than 20 feet long and is carrying a varying audio signal, extreme care must be taken. Very long lines (as they are called) are about 2 to 20 miles. They behave like a coupler and have an input and output impedance, as well as an internal impedance which is characteristic of the line. For the average line it is about 500 ohms. Engineers know that if the device that feeds into the line and the device that the line feeds into have 500 ohms impedance, the most efficient transmission will take place. Even with short lines of 20 feet or so this practice is quite essential especially if low signal levels are transmitted. The latter practice prevents induced noise from drowning out the signal.

Whenever a transmission line is employed reduce the impedance of the device feeding into it to 500 ohms, and at the end of the transmission line raise the 500 ohms to the input impedance of the unit. It is for this reason that it has become the practice to make input and output impedances of all standard voltage or power amplifiers 500 ohms.

Permanent transmission lines are usually a double wire within a lead shielded sheath. The two insulated wires are laid side by side, not twisted, and a lead covering placed over them. Shielding the cable prevents any induced signal from other parts of the system or the A.C. power lines. Short cables are preferable, of rubber covered flexible wire in a soft rubber sheath. Microphone or pickup wires should be as far away from output or A.C. wires as is possible. This will prevent "singing."

The placement of the microphone in the actual installation should be proper with reference to the speaker. It should never be placed in a line in front of the speaker. Reflected sound must not reach the microphone otherwise acoustic feed-back will take place and a singing noise will be heard, which is very annoying.

In ordinary installations outdoors, if the above precautions are followed and the horns are directed to the audience, but preferably away from fences or other reflecting surfaces, little difficulty will be experienced. With indoor installations the problem of a *perfect* sound installation is for the expert. In simple cases if the service man sees to it that the walls are not too bare, that there are drapes, broken wall and ceiling surfaces, and that there is sufficient upholstered furniture and enough people in the audience, intelligible sound will be heard.

REMOTE CONTROL RECEIVERS

Remote control in itself is a desirable feature in the tuning of a Radio set. It is convenient to be able to control the operation of a Radio receiver at a distant point. To the custom set builder, it is of particular interest since he may have an occasion of adding remote control in special installations.

Take for instance, in a special installation where the main tuning unit is in the living or drawing room, and broadcast reception is desired from auxiliary parallel fed reproducers located in the various other rooms, or even in the rooms on another floor away from the tuning unit. Remote control, giving at will satisfactory reception at any point, is a desirable feature in such an installation, and is a sales advantage in helping to put over an elaborate installation of this kind. A remote control should have the following features:

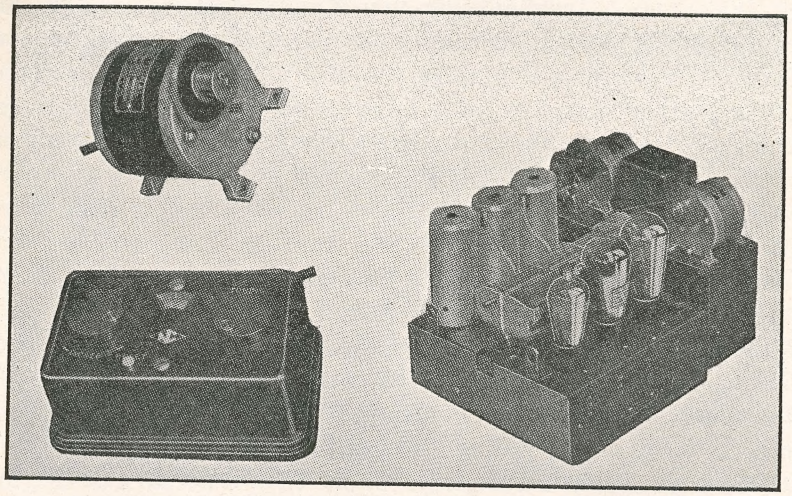


FIG. 8

1. Stop and start the Radio at any remote position.
2. Ability to control volume at any remote position.
3. Some visual indicator at remote point to determine frequency setting of station.
4. To be able to control the Radio at more than one position.

It is desirable to utilize a commercial remote control device which is easily attached to a standard commercial receiver. This

means that the mechanism, whether it be a motor or not, is easily attachable to the shaft of the tuning condenser of the receiver unit.

It is best to try to use a remote system which can be used universally with some satisfaction. At the present writing there is only one commercially developed remote control system recommended for general use—known as the Kinematic Remote Control.*

The mechanism of the remote control unit, which is attached to the shaft of the gang condenser, is a special synchronous motor and works on a step-by-step principle rotating the condensers in perfect synchronism with the rotation of the dial on the control box, which contains a similar motion following not only in speed but in degree of movement. By this method, the extreme accuracy of the Kinematic gives just as perfect and as close tuning at each box as can be obtained by hand at the set itself. This

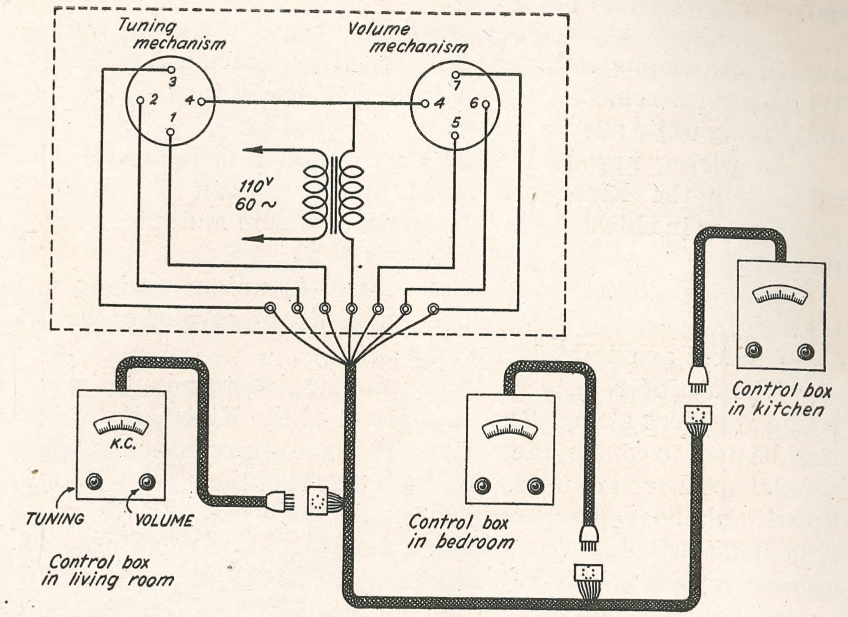


FIG. 9

* Sold by: Sleeper Research Corporation, New York City.
National Company, Malden, Mass.

step-by-step mechanism control unit is also used to control the volume of the receiver.

The Kinematic remote control consists of at least three units, one control mechanism for turning the condenser gang, one mechanism for turning the volume control and the remote dial tuning unit. (See Fig. 8.) This dial tuning unit has an adjustable knob for tuning the receiver, an adjustable knob for volume control in conjunction with an off and on switch, and a visual calibrated tuning dial, all at a remote point. If several remote positions are used, additional remote dial tuning units are required connected in parallel.

The Kinematic remote control is practical and easily attachable to any commercial type receiver with little change in design. When several remote positions are used, the Kinematic remote dial tuning units are arranged as shown in Fig. 9.

In wiring new houses for these special installations, the cables for the Kinematic remote positions can be properly planned for in shielded conduits to prevent hum and interference pick-up.

The installation of remote control is unique and advantageous in special systems where convenience, ease of operation and comfort are desired in a home.

The use of remote control is not limited to adaptation on Radio receivers alone. The mechanism of the Kinematic system may be used to control the volume from a given reproducer, when several speakers are used. The volume from the electrical pick-up with phonograph reproduction may also be controlled by the Kinematic principle from a remote point. In monitoring, voltage or current regulation, and many other applications where control is advantageous at a remote position, remote control devices of this type can be employed.

The remote control Radio has opened a field for wider development, as did the advent of the Radio vacuum tube for the sound and talking picture industry. Remote control is in its infancy and should be carefully watched for all future developments.

PERSONAL REVIEW QUESTIONS
ANSWERS NOT TO BE SENT IN FOR GRADING

TEST QUESTIONS

Number your answer sheet 15RA and add your *student number.*

Never hold up one set of lesson answers until you have another set ready to send in. Send each lesson in by itself before you start on the next lesson.

In that way, we shall be able to work together much more closely, you'll get more out of your Course, and the best possible lesson service.

1. If you were asked to build a portable receiver for use on a beach where there is no line power available, what kind of set would you build or recommend and how would you arrange for energy pick-up?
2. When a radio receiver is installed in a large interstate bus, what kind of an aerial is used and how is a ground obtained?
3. Would you use a dynamic or magnetic speaker with a portable receiver? Explain your answer.
4. Suppose you were installing a small P.A. system and you wanted to use a 400 ohm double button microphone feeding an amplifier having an input impedance of 500 ohms. What four devices would be required between the microphone and the amplifier input?
5. What is the purpose of a "mixer?"
6. How much power must be supplied by an amplifier used in a hospital to supply 400 sets of headphones, each of which requires .005 watt?
7. What are the 4 most important factors that must be considered in laying out amplifier systems for sound installations?
8. What will happen if a portable P.A. system is installed on a stage with the microphone on the front of the stage and the loudspeaker at the back of the stage?
9. What features besides that of tuning control must a remote control system have?
10. How is ignition interference originating at the spark plugs eliminated in an automobile?